Whisker Search on JCAA-JGPP Test Vehicle Boards

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Equipment Used:

- Fisher Scientific Micro master Microscope (optical microscope) with attached Canon Power Shot G10 Camera
- Fischer scope X-Ray XDAL (XRF)
- Hitachi TM-1000 Scanning Electron Microscope (SEM)

Sample Identification: Three boards were supplied:

- Test Vehicle ID Number 24, Manufactured Control Board
- Test Vehicle ID Number 94, Manufactured SAC Board
- Test Vehicle ID Number 133, Manufactured SACB Board

History of Test Vehicle Boards:

The three Test Vehicle Boards were thermally cycled 27,135 times. The thermal cycle used was -20°C to +80°C with dwell times of 30 minutes (hot dwell) and 10 minutes (cold dwell) and ramp rates of approximately 9.5°C/minute (cooling) and 7.2°C/minute (heating). The humidity in the thermal cycle chamber was not measured but was probably very low[1].

The table 1 below indicates the different components that we wanted to focus on for our search of tin whiskers. The boards have more components however we only focused on parts TQFP and TSOP because they have Sn and SnCu finishes, and are likely to whisker.

Table 1

	Reference Designator	Component	Component Finish	Reflow Solder Alloy
Test Vehicle ID Number 24	U1	TQFP-144	Sn	SnPb
	U7	TQFP-144	Sn	SnPb
	U20	TQFP-144	Sn	SnPb
	U25	TSOP-50	SnPb	SnPb
	U39	TSOP-50	SnPb	SnPb
	U41	TQFP-144	Sn	SnPb
	U58	TQFP-144	Sn	SnPb
Test Vehicle ID Number 94	U1	TQFP-144	Sn	Sn3.9Ag0.6Cu
	U7	TQFP-144	Sn	Sn3.9Ag0.6Cu
	U20	TQFP-144	Sn	Sn3.9Ag0.6Cu
	U25	TSOP-50	SnCu	Sn3.9Ag0.6Cu
	U29	TSOP-50	SnCu	Sn3.9Ag0.6Cu
	U39	TSOP-50	SnCu	Sn3.9Ag0.6Cu

**The three PWA boards do not have the same Reference Designator numbers between them because some components were missing or fell off the boards.*

**U1, U7, U20, U41, and U58 are common between the three boards.*

	U41	TQFP-144	Sn	Sn3.9Ag0.6Cu
	U58	TQFP-144	Sn	Sn3.9Ag0.6Cu
	U61	TSOP-50	SnCu	Sn3.9Ag0.6Cu

Test Vehicle ID Number 133	U1	TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi
	U7	TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi
	U20	TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi
	U41	TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi
	U58	TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi

Methodology: The test vehicle boards were first examined with the XRF to see that the component finish matched up with the data sheet and also to find out if the solder wet all the way up the pin lead. They were then inspected for whiskers through the optical microscope. To mark down the points of interest, a silver conductive paste was used, by putting a dot right above the pin lead. This makes it very easy to see visually and more importantly under the SEM. The specific components were cut and attached to the sample mount (see Figure 1) where they could be inserted into the SEM stage for further inspection. I used three different magnification ranges within the SEM: [2]

- Defining view (~120-180 X)
- Close-up (~200-500 X)
- Close examination (~600-3000 X)

Figure 1. Component mounted on Hitachi TM 1000 sample stage.

Whiskers on Sn Finish Parts

Figures 2-6 are whiskers taken from Test Vehicle ID 133, manufactured SACB. All four were found on the lower bend of the pin.

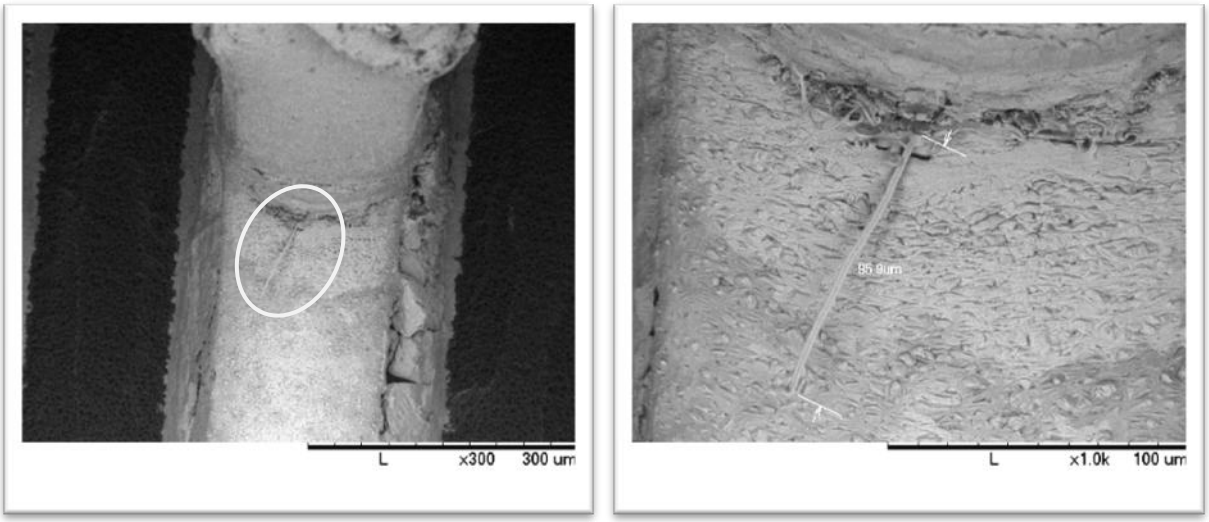

Figure 2. SEM image of the longest whisker found, 95µm long, on TQFP component U41.

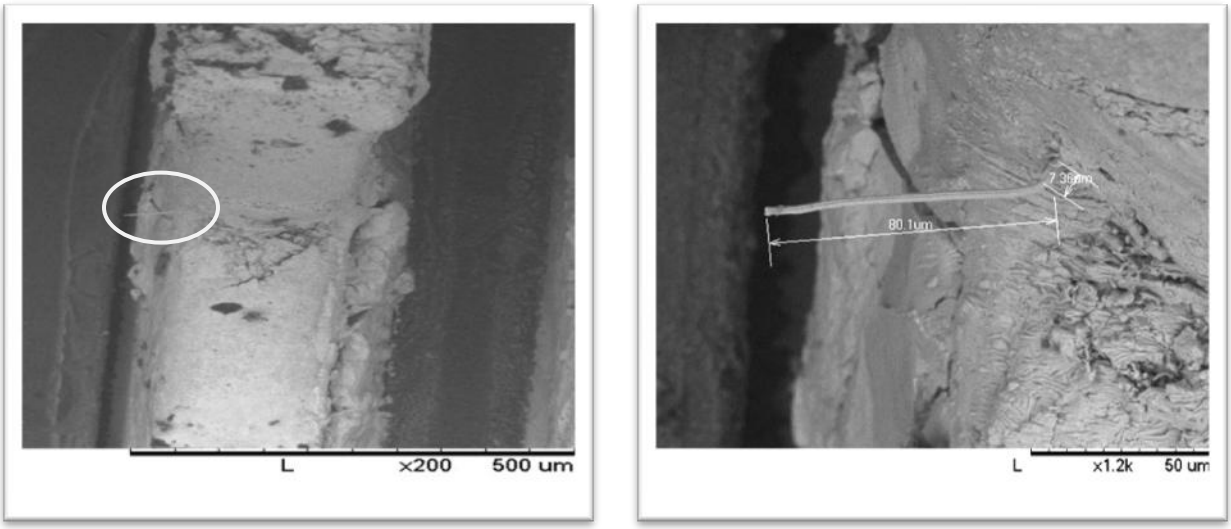

Figure 3. SEM image of the second longest whisker, 87µm long, on TQFP component U41. The whisker is coming from the side of the pin. However there are no other pins near by to cause a short seeing as it is coming from pin 1.

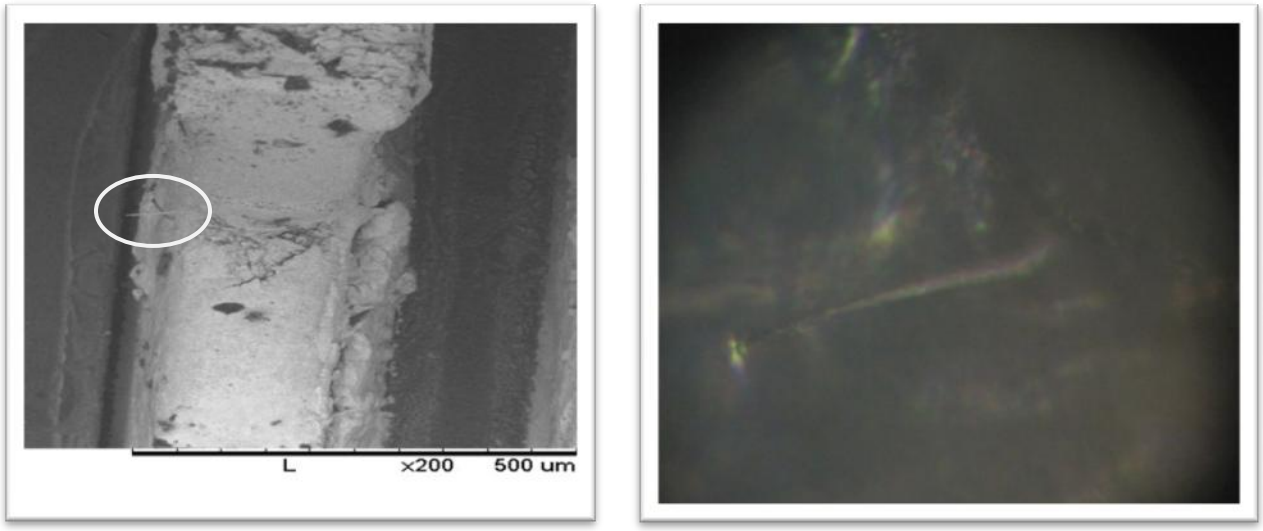

Figure 4. Same whisker as Figure 2 just that the second image shows the view of the optical microscope.

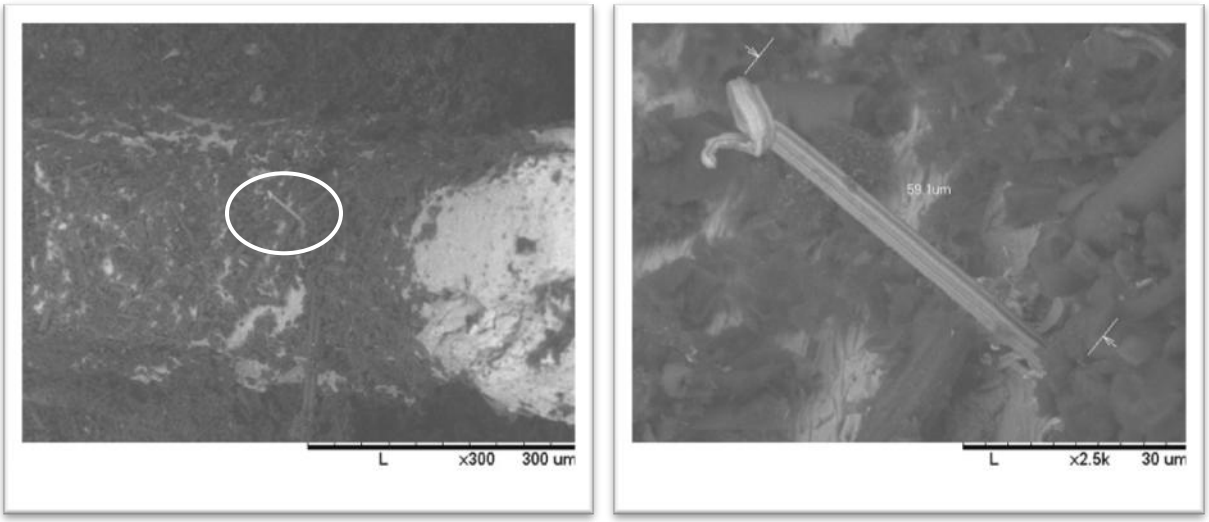

Figure 5. SEM image of a whisker 59µm long coming from TQFP component U1.

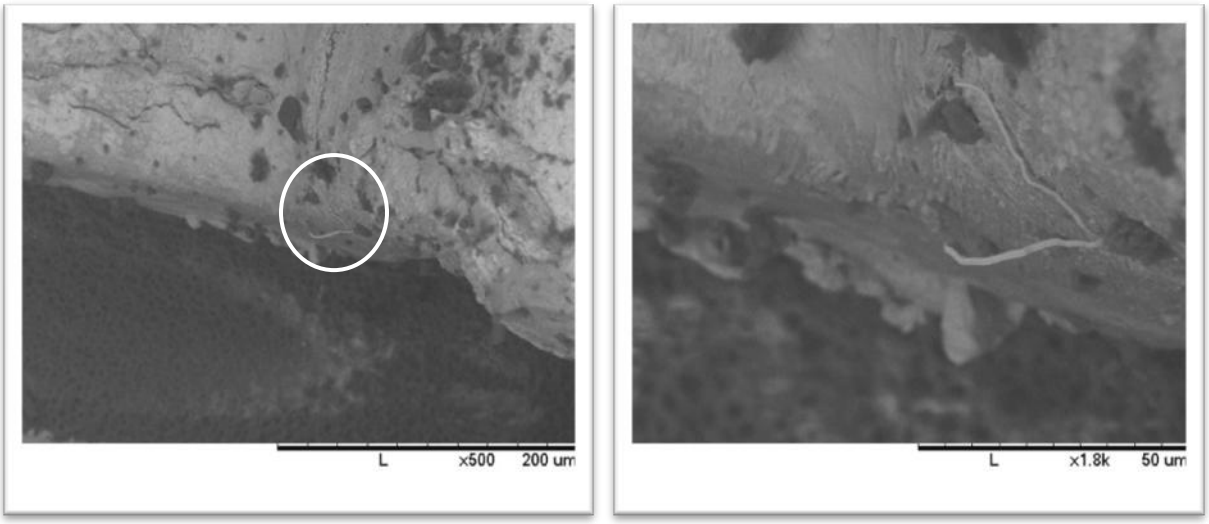

Figure 6. SEM image of two whiskers side by side on TQFP component U1.

Whiskers on SnCu Finish Parts

Figures 7 and 8 are whiskers taken from Test Vehicle ID 94, manufactured SAC board. All showed to have a high number of whiskers on the surface of the pins.

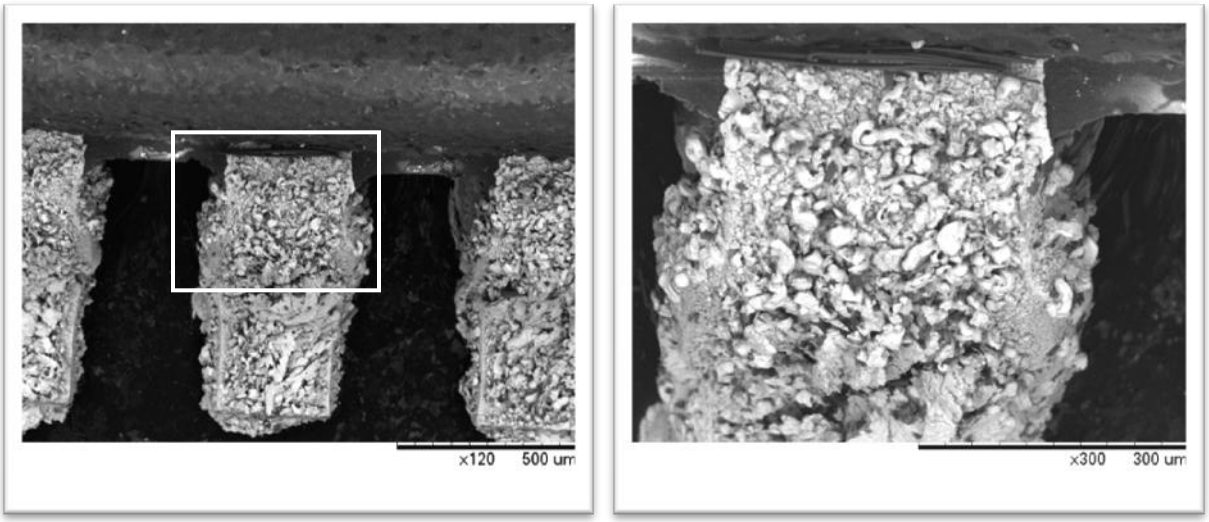

Figure 7. SEM image of a high number of whiskers on TSOP component U61.

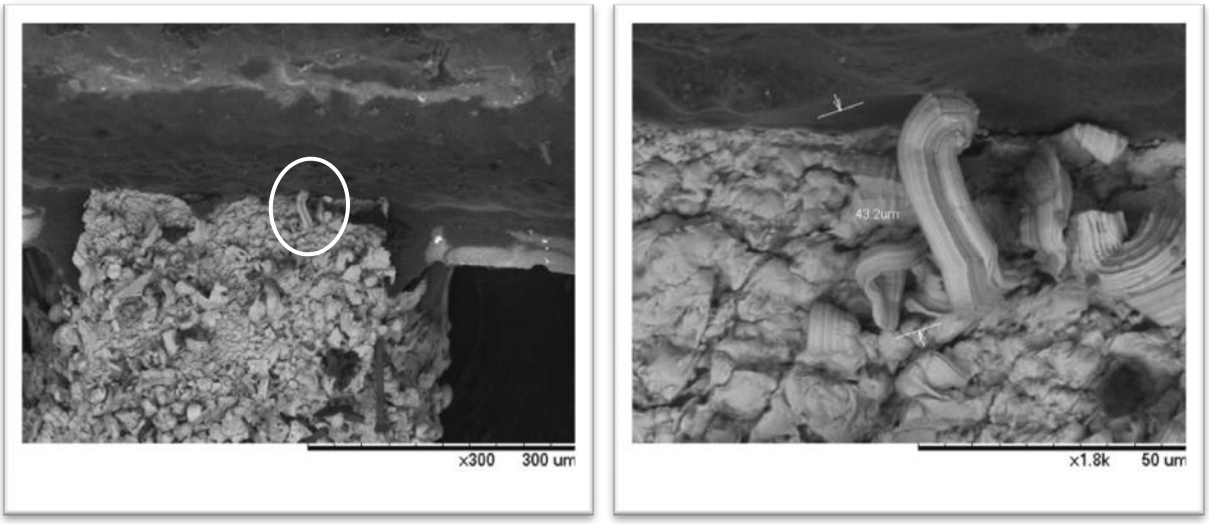

Figure 8. SEM image of one of the longer whiskers, 49 µm long, on TSOP component U61.

Figures 9 and 10 are from Test Vehicle ID 24 and were not included in the whiskers summary as being whiskers. They are not uniform or show any growth.

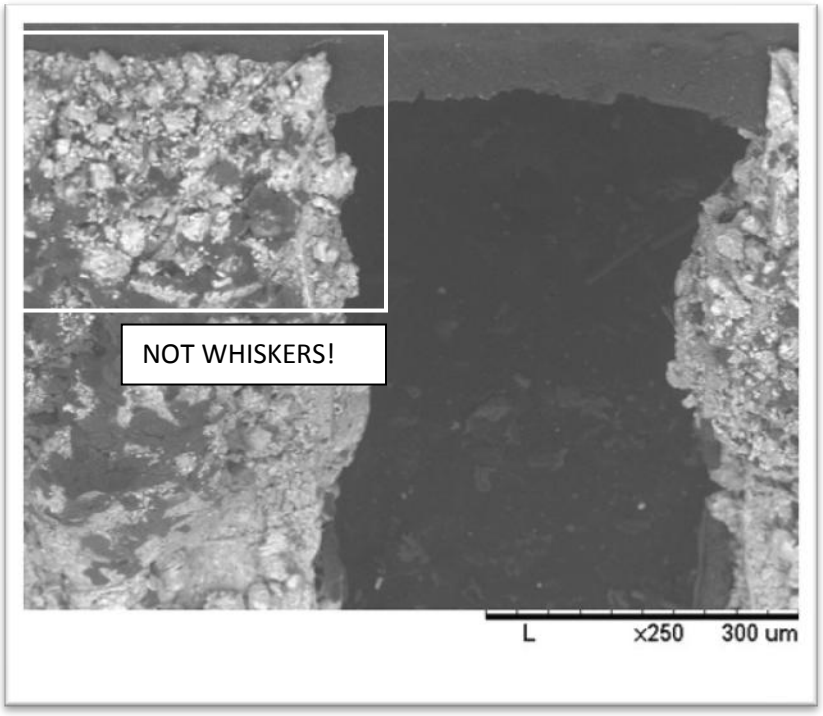

Figure 9. SEM image from TQFP component U39.

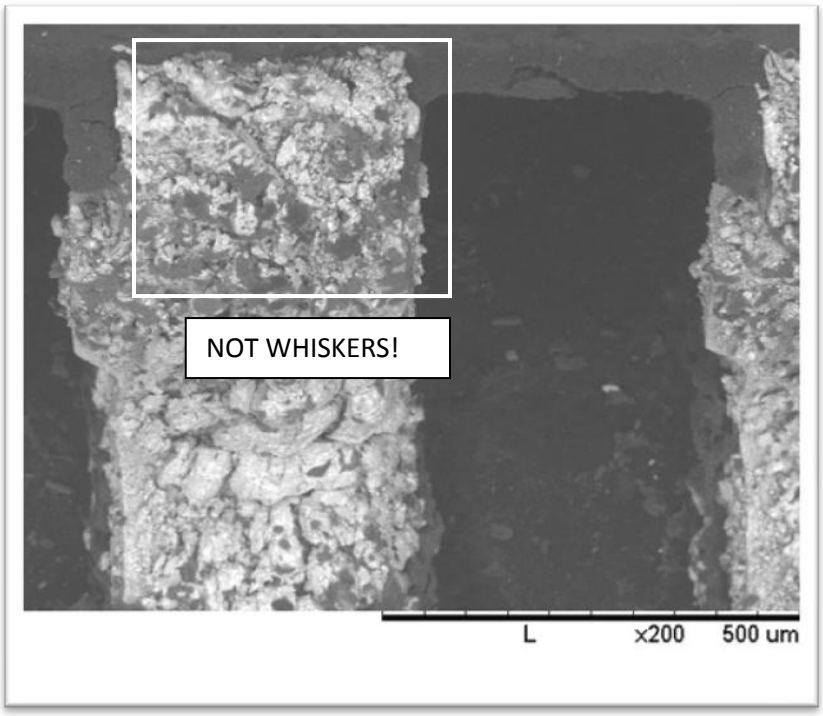

Figure 10. SEM image from TQFP component U39.

Table 2

Whisker Observation Summary					
Board ID	**Component**	**Component Finish**	**Reflow Solder Alloy**	**Whisker Density per lead** (See Table 3 Below)	**Length of Longest Observed Whisker (µm)**
Test Vehicle ID Number 24	*U1* TQFP-144	Sn	SnPb	Low	12
	U39 TSOP-50	SnPb	SnPb	Medium	33 (5µm typical)
Test Vehicle ID Number 94	*U1* TQFP-144	Sn	Sn3.9Ag0.6Cu	Low	30
	U7 TQFP-144	Sn	Sn3.9Ag0.6Cu	Low	12
	U41 TQFP-144	Sn	Sn3.9Ag0.6Cu	Low	20
	U58 TQFP-144	Sn	Sn3.9Ag0.6Cu	Low	17
	U61 TSOP-50	SnCu	Sn3.9Ag0.6Cu	High	45 (15µm typical)
Test Vehicle ID Number 133	*U1* TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi	Low	60
	U20 TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi	Low	40
	U41 TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi	Low	95
	U58 TQFP-144	Sn	Sn3.4Ag1Cu3.3Bi	Low	30

Table 3: JEDEC STANDARD [3]		
Maximum Whisker Density Range	**Total Number of Whiskers per Lead, Termination, or Inspected Coupon Area**	**Lead, Termination, or Coupon Inspection Area**
Low	< 10 whiskers	**(mm^2)**
Medium	10 – 45 whiskers	**(mm^2)**
High	> 45 whiskers	**(mm^2)**

Whisker density ranges that can be determined based on the number of whiskers observed per lead, termination, or coupon area. (In the case of the leads on the JGPP component TSOPs and TQFPs, we estimate the surface of each lead is a bit under 1.0 mm^2.)

Conclusion:

These boards had more of the traditional tin whiskers: long and thin. One can also notice the growth of the tin whiskers from the surface of the leads. Test Vehicle ID 133 which uses reflow solder alloy Sn3.4Ag1Cu3.3Bi had the longest tin whiskers ranging from 40-95µm. Component U61 from Test Vehicle ID Number 94 has the highest whisker density, having well over 45 tin whiskers per lead. SnCu finishes are said to be more prone to tin whiskers than others finishes. When we compare the SnCu vs. Sn finishes from Test Vehicle 94 it confirms that statement. Although there were no visible whiskers that shorted out another pin, the boards did have many different types of tin whiskers that were demonstrated in this report.

Other Tin Whisker Images Taken by the SEM

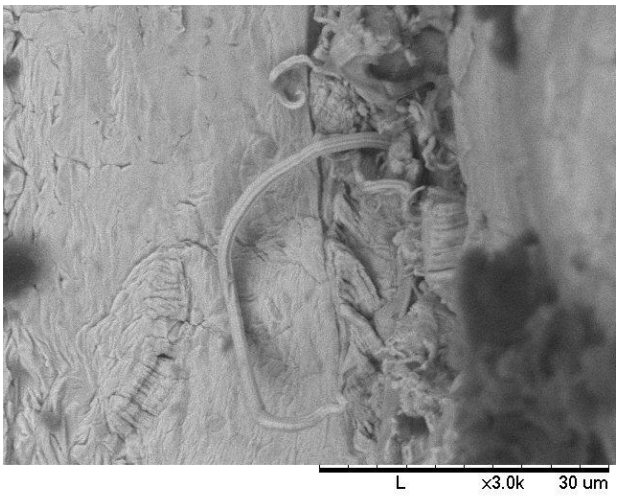

Figure 11.
Test Vehicle ID Number 133 Component U1

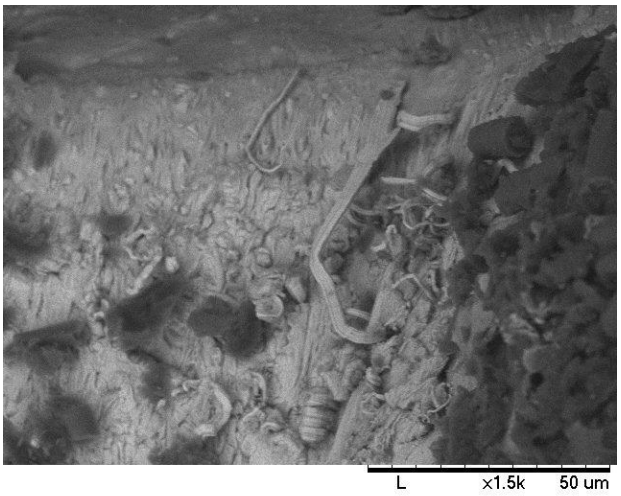

Figure 12.
Test Vehicle ID Number 133 Component U1

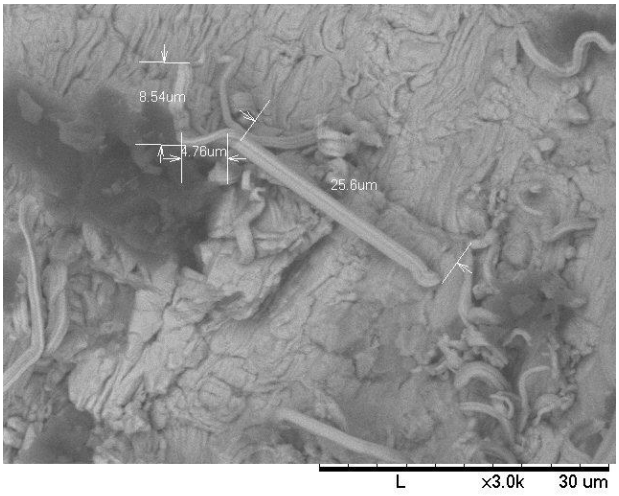

Figure 13.
Test Vehicle ID Number 133 Component U20

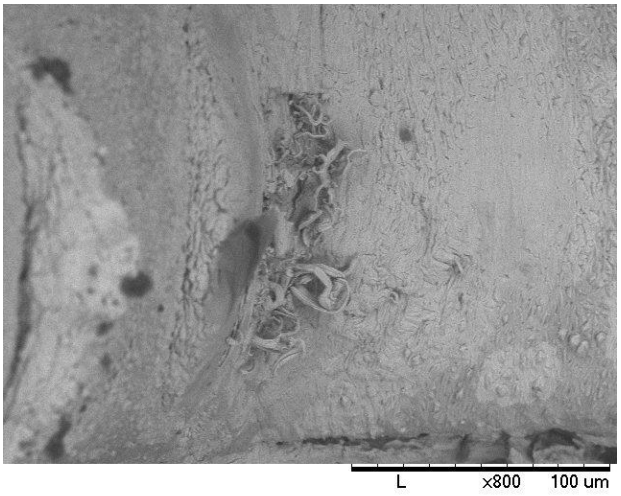

Figure 14.
Test Vehicle ID Number 133 Component U41

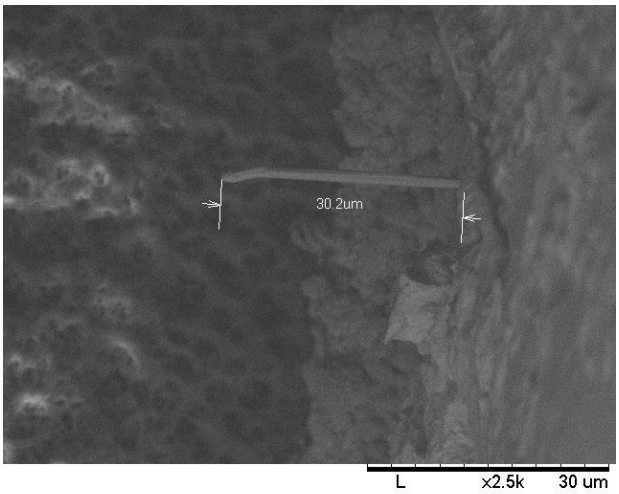

Figure 15.
Test Vehicle ID Number 94 Component U1

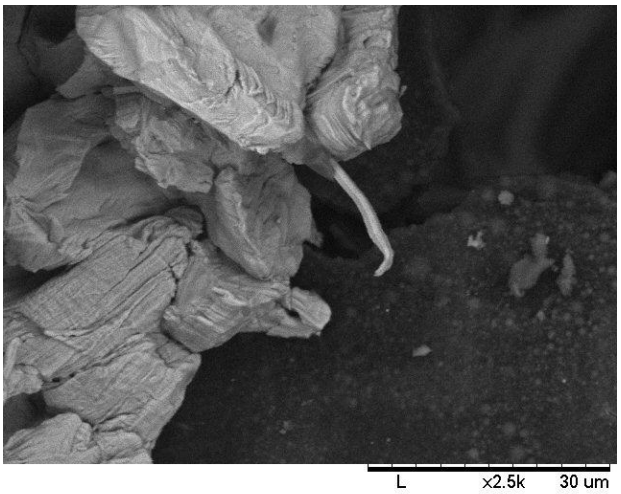

Figure 16.
Test Vehicle ID Number 94 Component U58

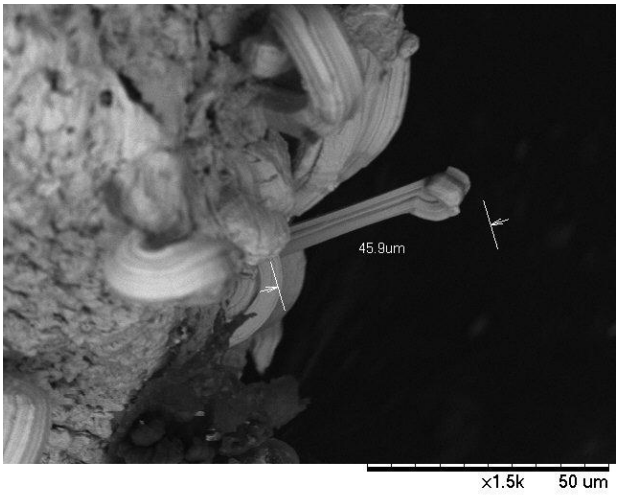

Figure 17.
Test Vehicle ID Number 94 Component U61

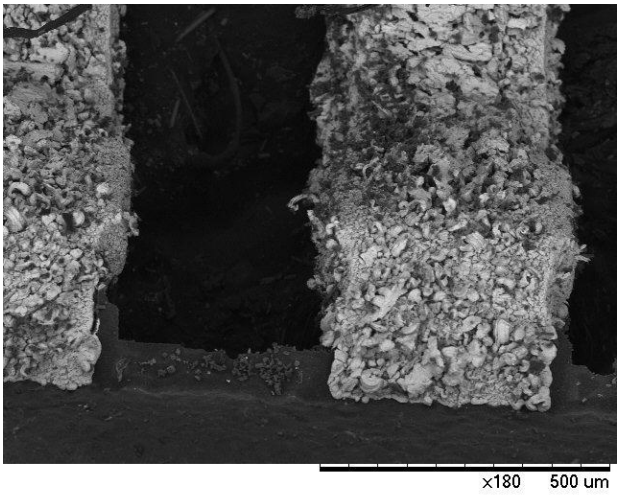

Figure 18.
Test Vehicle ID Number 94 Component U61

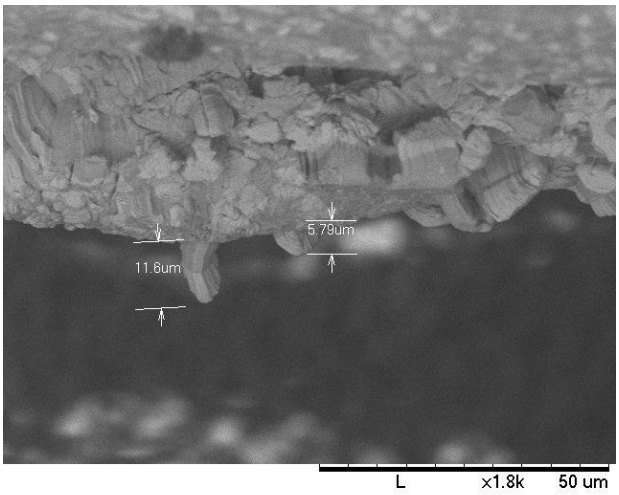

Figure 19.
Test Vehicle ID Number 24 Component U1

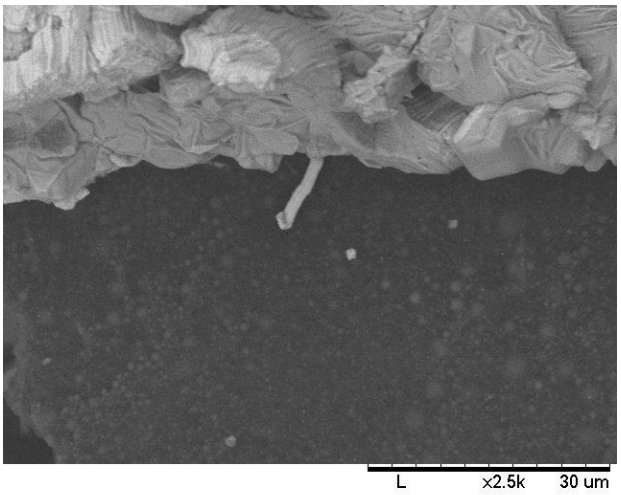

Figure 20.
Test Vehicle ID Number 24 Component U1

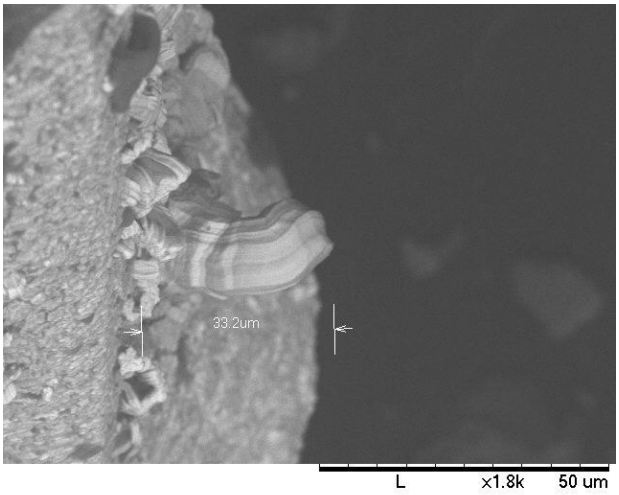

Figure 21.
Test Vehicle ID Number 24 Component U39

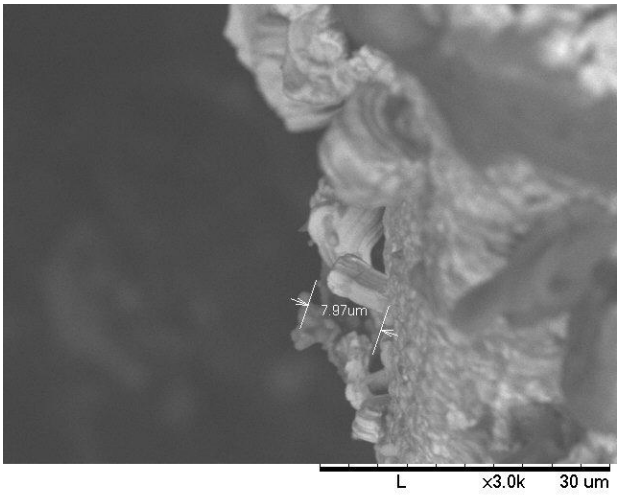

Figure 22.
Test Vehicle ID Number 24 Component U39

References

[1] Woodrow, Tom, "-20°C to +80°C Thermal Cycle Test," (Boeing Electronics Materials and Processes Report – 600 (EM/P-600)), Boeing MS&MT Thrust, October 31, 2008, from http://www.acqp2.nasa.gov/LFS%20Reliability/Woodrow/WoodrowThCycleEMP%20Final%20formatted%20for%20print.pdf

[2] M. J. Bozack and E. R. Crandall, "Whisker Search on Mechanical and Thermal Shock Components" Center for Advanced Vehicle and Extreme Environment Electronics (CAVE3) Auburn University, March 15, 2010.

[3] JEDEC STANDARD, JESD22-A121A, July 2008.